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Pattern of Research Collaboration of six Indian Institutes of Technology: A Scientometric Analysis

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Abstract - The study makes an analysis of 72940 papers indexed by Scopus International database and published by six Indian Institutes of Technology during 2006 to 2015 which indicates that scientists of six IITs are more inclined to publish their research papers in collaboration with other countries and international institutions as two third (66.65%) papers of six IITs are internationally collaborated with 459 countries from almost all regions of the World. However the dominant research collaborating countries among them included USA, UK, Germany, Canada, France, Australia, Japan, South Korea, Singapore, Sweden, Switzerland, China, Italy, etc. All the six IITs also published (33.34%) papers collaboration with 355 national institutes within India to publish their papers. The study also indicates that the average value of CC for six institutes is 0.96, which indicates collaborative pattern of six institutes are denoted by co-authored papers than solo authors. It also indicates that the multi and mega-authored papers have notably increased during the second block of 2011-2015 compared to 2006-2010 as CC is 1.03. Among 38 highly collaborative institutions, the highest (Seven) are from USA, and Purdue University, USA had the highest number of internationally collaborated papers with three IITs.

Keywords – Collaboration, co - authorship Index (CAI), Research papers and Indian Institutes of Technology

1. Introduction:

Collaboration is extremely important part of research. Transfer of knowledge, especially tacit knowledge, can be possible through Collaboration. There is increasing interest among

researchers and policy makers in the field of science and technology towards research collaboration. According to Beaver and Rosen¹, 1978 “professionalization and increased knowledge in science gave rise to the need for collaboration. No one became successful, unless he or she is able to get the cooperation of many others in their respective fields of research.” Papers written by multiple authors attract more citations than papers written by single authors. International Collaboration papers receive more respect and citations than Domestic or National Collaboration papers. International research collaboration is not only made for research excellence or creating impact but also generating strong strategic partnerships and obtaining knowledge.

The Indian Institutes of Technologies (IITs) have been recognized as the peninsula of perfection in the orbit of higher education in India. Initiated as a contraption in technological education apart from the stereotyped university system, the numbers of IITs have increased from the five IITs ingrained during the period 1950–63 to 23 in 2016. All over the world, degrees accorded by IITs are acknowledged and esteemed. In March 1946, the 22-member committee recommended for the establishment of four technical institutes to make essential enthusiasm and adaptability of an organization in light of augmenting knowledge in a wavering society. After taking assistance from international organizations or foreign governments initially four of the five IITs were established. The first IIT was established in May 1950 in Kharagpur (West Bengal), followed by IIT Bombay in 1958, Madras and Kanpur in 1959. By an act of 1961 known as the Institutes of Technology Act, these institutes were entitled as “institutions of national importance.” By an amendment to the 1961 act, the College of Engineering, established in New Delhi in 1961, was also re-titled as IIT Delhi in 1963. IIT Guwahati was established in 1994. Roorkee University was assimilated into the IIT system, becoming the seventh IIT. As a result, in 2001, there were seven institutes under the IIT system. At present there are 23 IITs spread all over India.

2. Review of Literature

Several studies in the past have been published in literature dealing with the research performance of countries, different subjects and institutions. Garg and Dwivedi², analyses Pattern of Collaboration in the discipline of Japanese Encephalitis during 1991 to 2010, papers indexed by Science Citation Index-Expanded. The results shows that Japanese

Encephalitis (JE) is a highly collaborative discipline as it was observed by the values of co-authorship index and the collaborative coefficient for different countries and different sub-fields. Singh, Gupta & Kumar³ taking various quantitative and qualitative indicators the study suggest a methodology for getting an idea about the relative performance of various subject fields of IIT Roorkee from 1993 to 2001. Walke and Dhawan⁴, analyses the size of publication and growth rate of Indian publications in material science during the period 1993-2001, focusing on modes of communication, areas of research priority of the scientists and pattern of collaboration. Bhatia, Mohan and Saiyed⁵, studied research swings in a leading institute based on annual reports for a span of 25 years. Singh⁶ analyzed the research performance of Indian Institute of Technology, Delhi in terms of publications, Collaboration and international participation and major research areas of study. Physics, Mathematics and Material science are the top research areas of IIT Delhi. Bornmann et al⁷ analyzed the worldwide ranking and mapping of universities and research-focused institutions based on publication and citation data. The web application presented in this paper makes an analysis to reveal centers of excellence in different fields worldwide. The URL of the web application is as follows: <http://www.excellencemapping.net>. Pradhan⁸ and Ramesh⁶ analyses 5378 papers published by Indian Institute of Technology Madras and 4430 papers published by Indian Institute of Technology Bombay respectively indexed by the Scopus database in the field of Engineering Sciences and its sub-field during 2006–2015. The results shows that researchers of both the IITs in the field of engineering sciences published their papers in global journals published from USA, UK and Germany and other countries of the West. Siwach, and Kumar⁹, investigates the publication output of Maharshi Dayanand University, Rohtak from 2000-2013 as indexed in Scopus database. The results showed that there was a steep rise in the number of publications was observed from 2009 onwards. Highest numbers of Collaborations was made with South korea, USA, Spain etc. Pradhan and Ramesh¹⁰ analyses 72940 papers indexed by Scopus during the period 2006-2015 and published by researchers of six Indian Institutes of Technology which indicate that the relative citation impact of IIT Roorkee and IIT Bombay are more than other IITs.

3. Objectives of the Study

The present study investigates the research collaboration pattern of six IITs during the period 2006-2015. The objectives of the study are -

- Identify the type of co-authorship pattern, to calculate co-authorship index and to measure the strength of co-authorship among six IITs using collaborative coefficient (CC) suggested by Ajiferuke;
- Identify the changes in two blocks of 2006-2010 and 2011-2015;
- Identify the magnitude and pattern of national (within the country) and International collaboration of six IITs;
- Identify the highly collaborative institutions of six IITs.

4. Data and Methodology

The data downloaded from Scopus International database has been used for the present study. Using affiliation search, Indian Institute of Technology was searched in Scopus and it resulted in the listing of all six IITs. Each IIT was selected one by one and its search was restricted to years 2006-2015 under "year tag". The study was undertaken in accordance with the data retrieved from Scopus of the Elsevier database for the period 2006-2015 using the following search strategy under "Affiliation search"(AF-ID ("Indian Institute of Technology Delhi"60032730) OR AF-ID ("Indian Institute of Technology Kharagpur"60004750) OR AF-ID ("Indian Institute of Technology Madras"60025757) OR AF-ID ("Indian Institute of Technology Bombay"60014153) OR AF-ID ("Indian Institute of Technology Kanpur"60021988) OR AF-ID ("Indian Institute of Technology Roorkee"60031818)) AND (LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2006)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "le") OR LIMIT-TO (DOCTYPE , "no"))

A total of 72940 papers are included in the analysis published by six IITs. Bibliographic details for each record included author(s) and their affiliation. Data was later boosted with the count of total authors, type of collaboration (National and International). Papers contributed by 3 or 4 authors were treated as multi-authored and the papers more than 4 authors are treated as mega authored papers. Indicators used for measuring co-authorship and collaboration have been narrated below.

4.1 Collaborative Coefficient (CC)

This measure has been framed by Ajiferuke and as defined by Price and Beaver, 1966 which is based on fractional productivity. The formula is

$$CC = 1 - \frac{\sum_{j=1}^k \left(\frac{1}{j}\right)^F j}{N}$$

In the above formula Fj denotes the number of *joint* authored papers; N denotes total number of papers published and k is the greatest number of authors per paper. Ajiferuke, 1988 states that “CC tends to zero as single authored papers dominate and to $1-1/j$ as joint authored papers dominate. This connotes that higher the value of CC, higher the probability of multi or mega authored papers of that institute.”

4.2 Co-authorship Index (CAI) – To study the change in the pattern of co-authorship during the period 2006-2015, Co-authorship Index (CAI) framed by Garg and Padhi, 2001 was used. CAI is computed as mentioned below.

$$CAI = \{(N_{ij}/N_{jo}) / (N_{oj}/N_{oo})\} \times 100$$

Where

N_{ij} : number of papers having j authors in block I ;

N_{io} : total output of block I ;

N_{oj} : number of papers having j authors for all blocks;

N_{oo} : total number of papers for all authors and all blocks.

$J = 1, 2, (3 \text{ or } 4), \geq 5$.

CAI=100 entails that an institution's co-authorship effort for a particular type of authorship coincide to the World average, CAI >100 indicates higher than average co-authorship effort and CAI < 100 implies lower than average co-authorship effort by that institute for a given type of authorship pattern.

5. Results and Discussions

5.1 Distribution of papers according pattern of authors during 2006-2015 of Six IITs

Distribution of output by single or solo authors, double, multi and mega authored papers along with values of CAI and CC for each institute is presented in the Table 5.1. The average value of CC for six institutes is 0.96, which indicates collaborative pattern of six institutes are denoted by co-authored papers than solo authors. IITM and IITR had more CC value than the average value of six IITs indicating these two IITs have more multi or mega authored papers. IITK had lower value of CC, indicating higher value of CAI for solo authored papers. IITD, IITKGP and IITB having the same values of CC with average value of six IITs i.e. 0.96.

Table 5.1 Distribution of papers according to pattern of authors

| Six Institutes | Single authored Papers (CAI) | Double authored Papers (CAI) | Multi authored Papers (CAI) | Mega authored Papers (CAI) | Total | Collaborative Coefficient (CC) |
|----------------|------------------------------|------------------------------|-----------------------------|----------------------------|-------------|--------------------------------|
| IITD | 555 (111) | 3957 (92) | 6482 (96) | 3110 (121) | 14104 | 0.96 |
| IITKGP | 500 (92) | 4681 (101) | 7326 (101) | 2666 (96) | 15173 | 0.96 |
| IITM | 349 (79) | 4335 (116) | 5503 (94) | 2045 (91) | 12232 | 0.97 |
| IITB | 436 (101) | 3489 (95) | 5425 (94) | 2648 (121) | 11998 | 0.96 |
| IITK | 516 (141) | 3405 (109) | 4808 (98) | 1510 (81) | 10239 | 0.94 |
| IITR | 248 (75) | 2354 (84) | 5311 (120) | 1281 (76) | 9194 | 0.97 |
| Total | 2604 (3.6) | 22221 (30.5) | 34855 (47.8) | 13260 (18.1) | 72940 (100) | 0.96 |

5.2 Pattern of authorship of six IITs during two blocks 2006-2010 and 2011-2015

How the change in pattern of co-authorship has taken place during the two blocks are presented in Table 5.2. It shows that the multi and mega-authored papers have notably increased during the second block of 2011-2015 compared to 2006-2010 as CC is 1.03. The values of CAI shown for different type of authorship pattern in two blocks indicate that CAI for single authors has fallen and CAI for multi and mega authors has rise during the second blocks of the study period. Thus, the co-authored papers of Six IITs are increasing during the period of study indicating team research is predominant the authorship pattern of six IITs.

Table 5.4.1 Pattern of authorship of six IITs during two blocks 2006-2010 and 2011-2015

| Period of Study | Single-authored Papers (CAI) | Double authored papers (CAI) | Multi authored Papers (CAI) | Mega authored Papers (CAI) | Total | Collaboration Coefficient (CC) |
|------------------------|-------------------------------------|-------------------------------------|------------------------------------|-----------------------------------|--------------|---------------------------------------|
| 2006-2010 | 1198 (109) | 8981 (95) | 15103 (102) | 5478 (97) | 30760 | 0.96 |
| 2011-2015 | 1406 (93) | 13240 (103) | 19752 (97) | 7782 (101) | 42180 | 1.03 |
| Total | 2604 | 22221 | 34855 | 13260 | 72940 | 0.96 |

5.3 International Collaboration

Papers of six IITs which are published collaboration with various countries more than 50 are collected and presented in Table 5.3, which shows that IITB (11117) has the highest number of papers published with International Collaboration followed by IITM (6101) and so on. Six IITs has 45.5% papers are internationally collaborated which is more than national collaboration papers. Also, IITB has highest 1770 papers collaboration with USA followed by IITM (1216) and so on. It is elicited from the Table 5.3 that highest numbers of papers of six IITs are collaborated with USA (6536) followed by Germany with 2580 papers, United Kingdom with 1828 papers in third position, France with (1369) papers in fourth position and Canada with (1201) papers in fifth position. It is also observed that researchers of six IITs Collaborated with 459 countries from almost all regions of the World. However the dominant research collaborating countries among them included USA, UK, Germany, Canada, France, Australia,

Japan, South Korea, Singapore, Sweden, Switzerland, China, Italy, etc. It is also observed that these six premier institutes collaborated with almost all the technological advanced countries of the world including neighboring Asian countries. Thus, it is crystal clear that scientists of six IITs are more prone to publish their research papers in collaboration with other countries and international institutions as two third papers of six IITs are internationally collaborated.

Table 5.3 International Collaboration

| Collaboration with other countries | | | | | | | | |
|---|----------------|-------------|---------------|-------------|-------------|-------------|-------------|--------------|
| Sl. No. | Country | IITD | IITKGP | IITM | IITB | IITK | IITR | Total |
| 1 | United States | 978 | 966 | 1216 | 1770 | 1188 | 418 | 6536 |
| 2 | United Kingdom | 334 | 325 | 256 | 560 | 223 | 130 | 1828 |
| 3 | Canada | 345 | 251 | 131 | 195 | 141 | 138 | 1201 |
| 4 | Germany | 314 | 492 | 499 | 722 | 337 | 216 | 2580 |
| 5 | France | 229 | 156 | 200 | 490 | 220 | 74 | 1369 |
| 6 | Australia | 145 | 127 | 225 | 334 | 111 | 74 | 1016 |
| 7 | Japan | 122 | 150 | 252 | 301 | 116 | 72 | 1013 |
| 8 | South Korea | 85 | 179 | 322 | 309 | 117 | 97 | 1109 |
| 9 | Hong Kong | 84 | | | | | | 84 |
| 10 | Singapore | 87 | 143 | 158 | 108 | 102 | 69 | 667 |
| 11 | Sweden | 78 | 64 | | 223 | 82 | | 447 |
| 12 | Switzerland | 76 | 50 | 168 | 242 | 60 | | 596 |
| 13 | Malaysia | 65 | 87 | 60 | | | 52 | 264 |
| 14 | Italy | 61 | 127 | 130 | 235 | 64 | 75 | 692 |
| 15 | China | | 75 | 191 | 354 | 60 | | 680 |
| 16 | Russia | | | 155 | 351 | | | 506 |
| 17 | Taiwan | | 67 | 148 | 53 | 51 | 53 | 372 |
| 18 | Spain | | 87 | 134 | 181 | 101 | 55 | 558 |
| 19 | Austria | | | 116 | 62 | | | 178 |
| 20 | Czech Republic | | | 114 | 299 | | | 413 |
| 21 | Poland | | | 114 | 292 | 59 | | 465 |
| 22 | Slovenia | | | 105 | | | | 105 |
| 23 | Brazil | | | | 288 | | | 288 |
| 24 | Netherland | | | | 277 | | | 277 |
| 25 | Croatia | | | | 258 | | | 258 |
| 26 | Mexico | | | | 160 | | | 160 |

| | | | | | | | | |
|----|------------------------|-------------|-------------|-------------|--------------|-------------|-------------|---------------------------------|
| 27 | Denmark | | | | 152 | | | 152 |
| 28 | South Africa | | 79 | | 144 | | 58 | 281 |
| 29 | Norway | | | | 137 | | | 137 |
| 30 | Finland | | | | 133 | 74 | | 207 |
| 31 | Greece | | | | 133 | | | 133 |
| 32 | Romania | | | | 136 | | | 136 |
| 33 | Hungary | | | | 126 | | | 126 |
| 34 | Cuba | | | | 120 | | | 120 |
| 35 | Slovakia | | | | 120 | | | 120 |
| 36 | Armenia | | | | 123 | | | 123 |
| 37 | Ukraine | | | | 121 | | | 121 |
| 38 | Peru | | | | 119 | | | 119 |
| 39 | Turkey | | | | 121 | | | 121 |
| 40 | Pakistan | | | | 75 | | | 75 |
| 41 | Serbia | | | | 72 | | | 72 |
| 42 | Thailand | | | | 69 | | | 69 |
| 43 | Austria | | | | 62 | | | 62 |
| 44 | Saudi Arabia | | | | | | 193 | 193 |
| 45 | Iran | | | | | | 67 | 67 |
| 46 | Sub Total | 3003 | 3425 | 4694 | 10027 | 3106 | 1841 | 26096 |
| | Other countries | | | | | | | |
| | (414) | 4975 | 3825 | 3971 | 1194 | 3955 | 4605 | 22544 |
| | Total | 4178 | 4550 | 6101 | 11117 | 4181 | 3045 | 48621 (66.65%) |

5.4 National Collaboration

Data on National collaboration are presented in Table 5.4 which shows that highest numbers of papers are collaborated with Bhabha Atomic Research Centre by three IITs namely, IITKGP, IITB and IIT Kanpur with 827 papers followed by Tata Institute of Fundamental Research with 498 papers (three IITs IITM, IITB and IITK), Indian Institute of Science with 461 papers (IITM, IITB and IITK). It is observed that six IITs are collaborating with regional institutes that are established in their areas. IITD made highest number of collaboration with National Physical Laboratory India (295), IITKGP made highest collaboration with Jadavpur University (328), IITM with Anna University (196), IITB with Bhabha Atomic Research Centre (524), IITK with “Bhabha Atomic Research Centre and Indian Institute of Technology, Kharagpur” (145) each

and IITR with National Institute of Hydrology India (145). All the six IITs published (33.34%) papers collaboration with national institutes. Thus, six IITs collaborated with 355 institutes within India to publish their papers.

Table 5.4 National Collaboration

| Sl. No. | Institutes within India | IITD | IITKGP | IITM | IITB | IITK | IITR | Total |
|---------|--|------|--------|------|------|------|------|-------|
| 1 | National Physical Laboratory India | 295 | | | | | | 295 |
| 2 | University of Delhi | 265 | | | | | | 265 |
| 3 | All India Institute of Medical Sciences | 187 | | | | | | 187 |
| 4 | Jamia Millia Islamia | 177 | | | | | | 177 |
| 5 | Delhi Technological University | 158 | | | | | | 158 |
| 7 | Inter University Accelerator Centre India | 136 | | | | | | 136 |
| 8 | Jawaharlal Nehru University | 128 | | | | | | 128 |
| 9 | Netaji Subhas Institute of Technology | 135 | | | | | | 135 |
| 10 | Jadavpur University | | 328 | | | | | 328 |
| 11 | National Institute of Technology Rourkela | | 215 | | | | | 215 |
| 12 | Vidyasagar University | | 175 | | | | | 175 |
| 13 | Indian Statistical Institute, Kolkata | | 147 | | | | | 147 |
| 14 | Bhabha Atomic Research Centre | | 158 | | 524 | 145 | | 827 |
| 15 | Bengal Engineering and Science University | | 130 | | | | | 130 |
| 16 | University of Calcutta | | 116 | | | | | 116 |
| 17 | Indian Institute of Technology, Guwahati | | 135 | 154 | | | | 289 |
| 18 | National Institute of Technology, Durgapur | | 110 | | | | | 110 |
| 19 | Indian Institute of Technology, Kanpur | | 106 | | | | | 106 |
| 20 | Anna University | | | 196 | | | | 196 |
| 21 | Indian Institute of Science | | | 169 | 164 | 128 | | 461 |
| 22 | Tata Institute of Fundamental Research | | | 166 | 232 | 100 | | 498 |

| | | | | | | | | |
|----|--|-------------|-------------|-------------|-------------|-------------|-------------|--------------------------------|
| 23 | Indira Gandhi Centre for Atomic Research | | | 185 | | | | 185 |
| 25 | Indian Institute of Technology, Bombay | | | 113 | | 107 | | 220 |
| 26 | Indian Space Research Organization | | | 127 | | | | 127 |
| 28 | Institute of Physics Bhubaneswar | | | | 362 | | | 362 |
| 29 | University of Rajasthan | | | | 362 | | | 362 |
| 30 | Panjab University | | | | 368 | | | 368 |
| 31 | University of Jammu | | | | 354 | | | 354 |
| 32 | Indian Institute of Technology Indore | | | | 256 | | | 256 |
| 33 | Saha Institute of Nuclear Physics | | | | 237 | | | 237 |
| 34 | Aligarh Muslim University | | | | 228 | | | 228 |
| 35 | Indian Institute of Technology, Madras | | | | 121 | | | 121 |
| 36 | National Institute of Science Education and Research | | | | 211 | | | 211 |
| 37 | Indian Institute of Technology, Kanpur | | | | 145 | | | 145 |
| 38 | Indian Institute of Technology, Kharagpur | | | | | 145 | | 145 |
| 39 | National Institute of Hydrology India | | | | | | 145 | 145 |
| 40 | Subtotal | 1481 | 1620 | 1110 | 3564 | 625 | 145 | 8545 |
| | Other Institutes (316) | 2035 | 2887 | 2875 | 777 | 3314 | 2986 | 15774 |
| | Total | 4416 | 4507 | 3985 | 4341 | 3939 | 3131 | 24319 33.34%) |

***Data taken of the institute which have collaboration above 100 papers**

5.5 Highly collaborative Institutions

Six IITs also make collaborations with Institutions of international repute, which is presented in Table 5.5. Which indicate that scientists of six IITs collaborate with authors from all over the World to publish their research papers. With Purdue University, USA, scientists of three IITs, IITD, IITM and IITB published highest number of papers i.e. 382 followed by University of Texas at Austin with 370 papers collaboration with IITB, IITK and IITR, 342 papers with

Institut fiziki vysokikh energii, USA by IITM and IITB, Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia, with 302 papers, and collaborated with IITM and IITB, University of Tokyo, Japan 298 papers collaboration with five IITs except IITKGP. If we add the institutes from the USA then 7 numbers of institutes are in the top list and highest numbers of papers are collaborated with the institutes of this country. From the point of National Institutes, Bhabha Atomic Research Centre, Bombay, “Indian Institute of Science, Bangalore, Tata Institute of Fundamental Research, Bombay, Punjab University, Punjab, Institute of Physics,” Bhubaneswar, University of Rajasthan, University of Jammu, Jadavpur University, Kolkata, National Physical Laboratory, India and University of Delhi are the top collaborators with the scientists of six IITs. It has been observed that highest numbers of papers are published by IITB collaboration with highest number of International Institutes. Thus it is elicited from the study that six IITs have collaboration with different international institutions.

Table 5.5 Highly collaborative Institutions

| Sl. No. | Name of the Institute | IITD | IITKGP | IITM | IITB | IITK | IITR | Total |
|---------|--|------|--------|------|------|------|------|-------|
| 1 | Bhabha Atomic Research Centre, Bombay, India | | 158 | | 524 | 145 | | 827 |
| 2 | Indian Institute of Science, Bangalore, India | | | 169 | 164 | 128 | | 461 |
| 3 | Tata Institute of Fundamental Research, Bambaay, India | | | 166 | 232 | 100 | | 498 |
| 4 | Purdue University, USA | 25 | | 65 | 292 | | | 382 |
| 5 | University of Texas at Austin, USA | | | | 28 | 260 | 82 | 370 |
| 6 | Institut fiziki vysokikh energii, USA | | | 90 | 252 | | | 342 |
| 7 | Punjab University, India | | | | 368 | | | 368 |
| 8 | Institute of Physics Bhubaneswar, India | | | | 362 | | | 362 |
| 9 | University of Rajasthan, India | | | | 362 | | | 362 |
| 10 | University of Jammu, India | | | | 354 | | | 354 |
| 11 | Jadavpur University, India | | 328 | | | | | 328 |
| 12 | Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia | | | 97 | 205 | | | 302 |

| | | | | | | | | |
|----|--|-----|-----|-----|-----|-----|--|-----|
| 13 | National Physical Laboratory, India | 295 | | | | | | 295 |
| 14 | Ohio State University, USA | | | 25 | 257 | | | 282 |
| 15 | Henryk Niewodniczanski Institute of Nuclear Physics of the Polish Academy of Sciences, Poland | | | 95 | 181 | | | 276 |
| 16 | Joint Institute for Nuclear Research, Dubna, Russia | | | | | 266 | | 266 |
| 17 | University of Delhi, India | 265 | | | | | | 265 |
| 18 | Lawrence Berkeley National Laboratory, USA | | | | 258 | | | 258 |
| 19 | Indian Institute of Technology Indore, India | | | | 256 | | | 256 |
| 20 | Yale University, USA | | | | 254 | | | 254 |
| 21 | Nuclear Physics Institute of the Academy of Sciences of the Czech Republic v. v. i., Czech Republic. | | | | 253 | | | 253 |
| 22 | Politechnika Warszawska, Poland | | | | 253 | | | 253 |
| 23 | National Research Nuclear University MEPhI, Russia | | | | 253 | | | 253 |
| 24 | Pusan National University, South Korea | | | | 251 | | | 251 |
| 25 | Creighton University | | | | 251 | | | 251 |
| 26 | Saha Institute of Nuclear Physics, India | | | | 237 | | | 237 |
| 27 | University of Birmingham, UK | | | | 230 | | | 230 |
| 28 | Universidade de Sao Paulo - USP, Brazil | | | | 229 | | | 229 |
| 29 | Aligarh Muslim University, India | | | | 228 | | | 228 |
| 30 | University of Science and Technology of China, China | | | 92 | 134 | | | 226 |
| 31 | Korea Institute of Science and Technology Information, South Korea | | | 98 | 126 | | | 224 |
| 32 | Universidade Estadual de Campinas, Brazil | | | | 223 | | | 223 |
| 33 | Indian Institute of Technology, Bombay | | | 113 | | 107 | | 220 |
| 34 | National Institute of | | 215 | | | | | 215 |

| | | | | | | | | |
|----|---|-----|-----|------|------|------|----|-------|
| | Technology Rourkela, India | | | | | | | |
| 35 | Pennsylvania State University, USA | | | | 159 | 56 | | 215 |
| 36 | Johann Wolfgang Goethe Universitat Frankfurt am Main, Germany | | | | 208 | | | 208 |
| 37 | Utrecht University, Netherlands | | | | 207 | | | 207 |
| 38 | Ceske vysoke uceni technicke v Praze, Czech Republi | | | | 203 | | | 203 |
| | Total | 585 | 701 | 1010 | 7794 | 1062 | 82 | 11234 |

*Data taken for those International Institute published more than 200 papers with six IITs

Conclusion – The study indicates that collaborative pattern of six institutes are denoted by co-authored papers than solo authors. It also indicates that the multi and mega-authored papers have notably increased during the second block of 2011-2015 compared to 2006-2010 as CC is 1.03. IIT Madras and IIT Roorkee had more CC value than the average value of six IITs indicating these two IITs have more multi or mega authored papers than other IITs. Papers published in international collaboration are almost twice the papers written in domestic collaboration. Highest numbers of collaborating institutions are belongs to USA with seven institutes.

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